

# **TOPIC 13 – PERIODICITY**

## **13.2 – FIRST-ROW D-BLOCK ELEMENTS**

IB Chemistry  
T13D02



# 13.2 – First-row d-block Elements

- 13.2.1 List the characteristic properties of transition elements. (1)
- 13.2.2 Explain why Sc and Zn are not considered to be transition elements. (3)
- 13.2.3 Explain the existence of variable oxidation number in ions of transition elements. (3)
- 13.2.4 Define the term ligand. (1)
- 13.2.5 Describe and explain the formation of complexes of d-block elements. (3)
- 13.2.6 Explain why some complexes of d-block elements are colored. (3)
- 13.2.7 State examples of the catalytic action of transition elements and their compounds. (1)
- 13.2.8 Outline the economic significance of catalysts in the Contact and Haber processes. (2)



## 13.2

# Properties of the Transition Metals

## 13.2.1 List the characteristic properties of transition elements. (1)

- First-row d-block consist of 10 elements
  - The 10 electrons that fill the 3d sub-shell are responsible for the characteristics
  - Eight are classified as transition elements
    - First (Sc) and Last (Zn) are not considered to be transition metals since they don't share the properties of the rest
  - Properties of transition elements
    - High densities, low M.P. and B.P.
    - Ability to exist in multiple oxidation states
    - Formation of colored ions
    - Ability to form complex ions through dative bonds
    - Act as catalysts



## 13.2 Exceptions to the T-metals (Sc & Zn)

### 13.2.2 Explain why Sc and Zn are not considered to be transition elements. (3)

- Sc and Zn do not display the properties of transition metals
  - Sc has only one electron in the d orbital
  - Zn has a complete outer shell
- A **transition metal** is defined as a d-block metal that forms at least one stable cation with an incomplete 3d sub-shell.
  - Sc and Zn cannot achieve this.
  - Cu can as  $\text{Cu}^{2+}$



# Electron Configuration of T-metals

El.	#	Noble Not.	#	3d					4s
Sc	21	[Ar]3d <sup>1</sup> 4s <sup>2</sup>	[Ar]	↑					↑ ↓
Ti	22	[Ar]3d <sup>2</sup> 4s <sup>2</sup>	[Ar]	↑	↑				↑ ↓
V	23	[Ar]3d <sup>3</sup> 4s <sup>2</sup>	[Ar]	↑	↑	↑			↑ ↓
Cr	24	[Ar]3d <sup>5</sup> 4s <sup>1</sup>	[Ar]	↑	↑	↑	↑	↑	↑
Mn	25	[Ar]3d <sup>5</sup> 4s <sup>2</sup>	[Ar]	↑	↑	↑	↑	↑	↑ ↓
Fe	26	[Ar]3d <sup>6</sup> 4s <sup>2</sup>	[Ar]	↑ ↓	↑	↑	↑	↑	↑ ↓
Co	27	[Ar]3d <sup>7</sup> 4s <sup>2</sup>	[Ar]	↑ ↓	↑ ↓	↑	↑	↑	↑ ↓
Ni	28	[Ar]3d <sup>8</sup> 4s <sup>2</sup>	[Ar]	↑ ↓	↑ ↓	↑ ↓	↑	↑	↑ ↓
Cu	29	[Ar]3d <sup>10</sup> 4s <sup>1</sup>	[Ar]	↑ ↓	↑ ↓	↑ ↓	↑ ↓	↑ ↓	↑
Zn	30	[Ar]3d <sup>10</sup> 4s <sup>2</sup>	[Ar]	↑ ↓	↑ ↓	↑ ↓	↑ ↓	↑ ↓	↑ ↓

## 13.2

# Variable Oxidation States

## 13.2.3 Explain the existence of variable oxidation number in ions of transition elements. (3)

- The most common oxidation state is 2+ as the 4s electrons are lost to form an  $M^{2+}$  ion
- The maximum stable oxidation state would be the loss of all available **bonding** electrons
  - $Mn(3d^5 4s^2) \rightarrow Mn^{7+}([Ar])$
  - $Fe(3d^6 4s^2) \rightarrow Fe^{3+}([Ar]3d^5)$
- The variable oxidation states are due in part to the relatively small energy difference between the 3d and 4s sub-shells.



# Common Ions

Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn
+3	+2 +4	+2 +3 +4 +5	+2 +3  +6	+2  +4  +6 +7	+2 +3	+2 +3	+2	+1 +2	+2

- As elements become ionized, energy must be supplied to overcome the ionization energy. Therefore all ionization is considered to be **endothermic**



# Ligands

## 13.2.4 Define the term ligand. (1)

- A d-block metal **complex-ion** consists of a d-block metal ion surrounded by a definite number of **ligands**.
  - These are molecules or negative ions with lone pairs of electrons
  - Common ligands are:  $\text{H}_2\text{O}$ ,  $\text{NH}_3$ ,  $\text{Cl}^-$ ,  $\text{OH}^-$ ,  $\text{CN}^-$ 
    - Also known as nucleophiles as they are attracted to the positive charge of a nucleus (in this case the effective nuclear charge of an ion).
  - Ligands share their lone pair with the empty orbitals in the central d-block



The ligands be have as Lewis Bases ( $e^-$  pair donors –  
Topic 08/18)

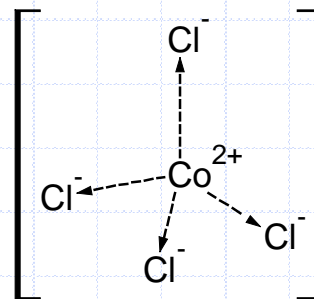
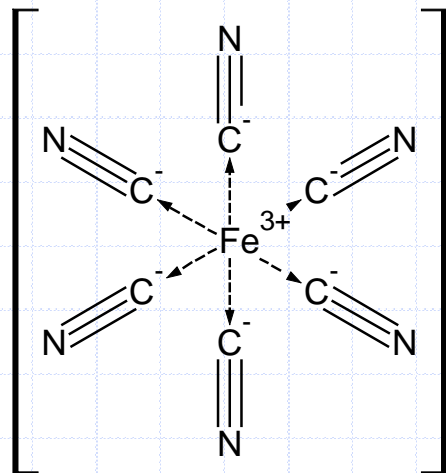


## 13.2

# Formation of Complex Ion Compounds

## 13.2.5 Describe and explain the formation of complexes of d-block elements.

- The coordination number is simply the number of ligands attached to the ion:
  - $[\text{Fe}(\text{CN})_6]^{3-}$  coordination of 6
  - $[\text{Co}(\text{Cl})_4]^{2-}$  coordination of 4



- The net charge on all ions must be zero, so each will pick up an anion as in a salt

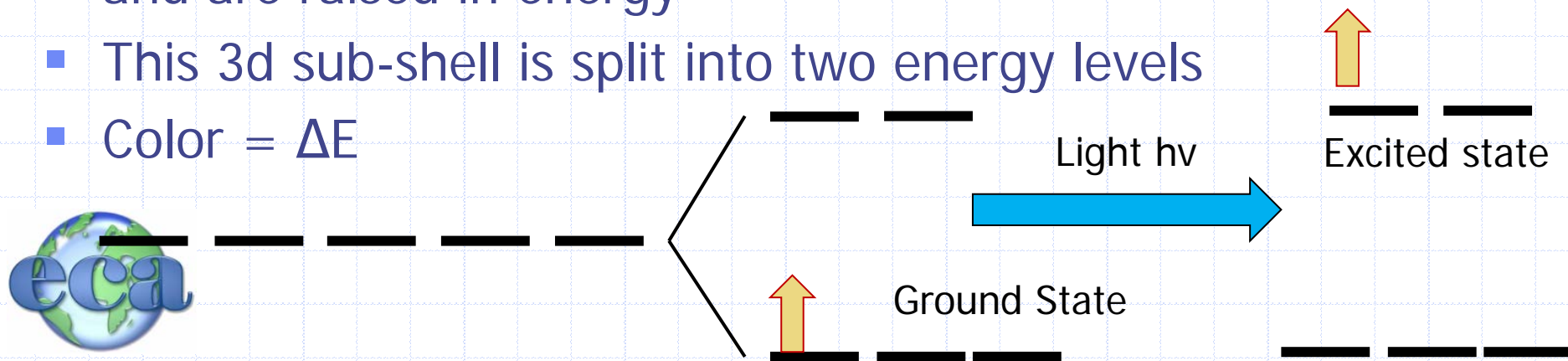


## 13.2

# Colored Compounds

## 13.2.6 Explain why some complexes of d-block elements are colored. (3)

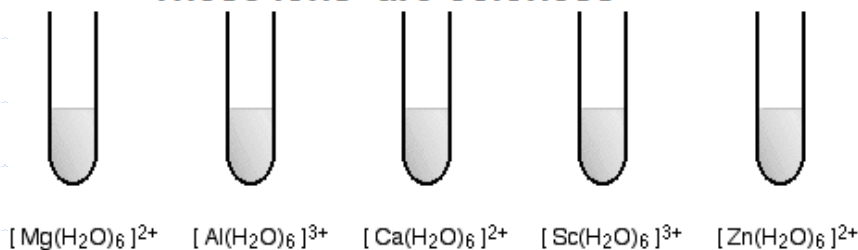
- Most d-block metal compounds are colored, both in solution and in the solid state.
- The colors are due to the presence of incompletely filled 3d sub-shells
- In an isolated gaseous d-block metal, the five 3d subshells are of equal energy and different orientations
- In a complex ion, the 3d sub-shells are oriented relative to the ligands – those close to the ligand experience repulsion and are raised in energy
- This 3d sub-shell is split into two energy levels
- $\text{Color} = \Delta E$



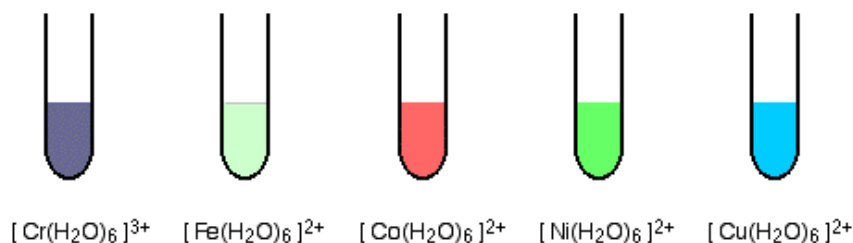
# Where does the color come from?

- Factors that affect the color:
  - Nuclear Charge
  - Number of d-electrons
  - Nature of the ligand

**These ions are colorless**



**Complex ions have distinct colors**



## 13.2

# Transition Metals as Catalysts

13.2.7 State examples of the catalytic action of transition elements and their compounds. (1)

- We will revisit transition metals as Catalysts in Topic 06 - Kinetics



## 13.2

# Economic Significance of Catalysts

## 13.2.8 Outline the economic significance of catalysts in the Contact and Haber processes. (2)

- We will revisit transition metals at catalysts in Topic 06/16 - Kinetics

